REMARKS

In the last Office Action, the Examiner requested a copy of reference AR listed in Form PTO-1449 submitted with the information disclosure statement (IDS) filed June 20, 2007. The title of the invention was objected to as not being descriptive. Claims 9 and 16-19 were rejected under 35 U.S.C. §103(a) as being unpatentable over Shimizu (US 4,888,512) in view of Hendershot ("Design of Brushless Permanent Magnet Mortors"). Claim 20 was rejected under 35 U.S.C. §103(a) as being unpatentable over Shimizu in view of Hendershot and further in view of Horikawa (US 5,062,095). Additional art was cited of interest.

In accordance with the present response, independent claims 9 and 16 have been amended to further patentably distinguish from the prior art of record. Non-elected claims 7, 8, 10-15, and 21-24 have been canceled without prejudice or admission and subject to applicants' right to file one or more continuing applications to pursue the subject matter of the non-elected claims. New claims 25-34 have been added to provide a fuller scope of coverage. The title of the invention has been changed to "PERMANENT MAGNET AND MOTOR EQUIPPED WITH PERMANENT MAGNET" and the previously submitted abstract has been revised to more clearly reflect the invention to which the amended and new claims are directed.

As requested by the Examiner, applicants submit herewith a copy of reference AR listed in Form PTO-1449 submitted with the IDS filed June 20, 2007. Applicants respectfully request consideration of reference AR in accordance with the June 20 IDS.

Applicants request reconsideration of their application in light of the foregoing amendments and the following discussion.

The present invention is directed to a permanent magnet and to a motor equipped with the permanent magnet.

As described in the specification, conventional permanent magnets suffer from the inability of achieving full magnetization (i.e., magnetic saturation), thereby affecting the potential magnetic properties of the permanent magnets. The conventional permanent magnets are also not sufficiently compact, thereby increasing the overall size of motors equipped with such conventional permanent magnets.

The present invention overcomes the drawbacks of the conventional art. Figs. 1 and 3 show a magnet for a rotor of an outer rotor type motor 30 according to the present invention embodied in the claims. The magnet comprises a cylindrical-shaped permanent magnet 3 having a plurality of magnetic domains (e.g., 33-35) magnetized in a radial direction and arranged at regular intervals in a circumferential direction. A thickness t in the radial

direction of the permanent magnet 3 satisfies the relation of $t \leq \pi D/(NM - \pi)$, where D represents an inner diameter of the permanent magnet 3 having a value of 20 mm or less, N represents the number of the magnetic domains, and M represents the number of alternating current phases for driving the outer rotor type motor 30.

In another aspect, the present invention is directed to a motor equipped with the permanent magnet according to the present invention. With reference to the embodiment shown in Fig. 1, the motor 30 has a rotor portion 1 having a rotational body 7, a rotational shaft 6 arranged on an axial line of the rotational body 7, and a permanent magnet 3 arranged around the rotational body 7. The permanent magnet has a plurality of magnetic domains (e.g., 33-35) magnetized in a radial direction and arranged at regular intervals in a circumferential direction, a thickness t in the radial direction of the permanent magnet 3 satisfying the relation of $t \leq \pi D/(NM - \pi)$, where D represents an inner diameter of the permanent magnet 3 having a value of 20 mm or less, N represents the number of the magnetic domains, and M represents the number of alternating current phases for driving the motor. A stator portion 2 has a plurality of stator coils 4 excitable with alternating current. The permanent magnet 3 surrounds an outer circumference of the stator portion 2 so that the stator coils 4 confront an inner

peripheral surface of the permanent magnet 3. A bearing portion 5 rotatably and pivotally supports the rotational shaft 6 relative to the stator portion 2 so that the rotational body 7 and the stator coils 4 are concentric to each other.

By the foregoing construction, the magnet according to the present invention provides a permanent magnet which is capable of achieving full magnetization to thereby provide a magnet with enhanced magnetic performance. The permanent magnet is also sufficiently compact, thereby reducing the overall size of the motor (e.g., an outer rotor type motor) equipped with the permanent magnet.

Applicants respectfully submit that amended claims 9 and 16, dependent claims 17-20, and newly added claims 25-34 patentably distinguish from the prior art of record.

Claims 9 and 16-19 were rejected under 35 U.S.C. §103(a) as being unpatentable over Shimizu in view of Hendershot. Applicants respectfully traverse this rejection.

Independent Claim 9

Amended independent 9 is directed to a magnet for a rotor of an outer rotor type motor and requires a cylindrical-shaped permanent magnet having a plurality of magnetic domains magnetized in a radial direction and arranged at regular intervals in a circumferential direction. Claim 9 further

requires that a thickness t in the radial direction of the permanent magnet satisfies the relation of $t \le \pi D/(NM - \pi)$, where D represents an inner diameter of the permanent magnet having a value of 20 mm or less, N represents the number of the magnetic domains, and M represents the number of alternating current phases for driving the outer rotor type motor. No corresponding structural combination is disclosed or suggested by the combined teachings of Shimizu and Hendershot.

Shimizu discloses a permanent magnet for a motor. As recognized by the Examiner, the permanent magnet in Shimizu does <u>not</u> have a thickness in the radial direction thereof satisfying the relation $t \le \pi D/(NM - \pi)$, as recited in independent claim 9.

Moreover, Shimizu does <u>not</u> teach a permanent magnet for a rotor of an <u>outer rotor type motor</u>, where M in the relation of $t \le \pi D/(NM - \pi)$ represents the number of alternating current phases for driving the <u>outer rotor type motor</u>, as recited in amended independent claim 9. In this regard, Shimizu teaches an inner hub spindle motor (Fig. 6) and a PM-type stepping motor (Fig. 8) incorporating magnets 38 and 45, 45', respectively. However, these motors are <u>not outer rotor type motors</u>, as recited in amended claim 9.

The secondary reference to Hendershot discloses brushless permanent magnet motors, but does <u>not</u> teach <u>outer</u>

rotor type motors, as recited in amended claim 9. Accordingly, Hendershot does not cure the deficiencies of Shimizu, and one ordinarily skilled in the art would not have been led to modify the references to attain the claimed subject matter.

Independent Claim 16

Amended independent claim 16 is directed to a motor and requires a rotor portion having a rotational body, a rotational shaft arranged on an axial line of the rotational body, and a permanent magnet arranged around the rotational body, the permanent magnet having a plurality of magnetic domains magnetized in a radial direction and arranged at regular intervals in a circumferential direction, a thickness t in the radial direction of the permanent magnet satisfying the relation of $t \leq \pi D/(NM - \pi)$, where D represents an inner diameter of the permanent magnet having a value of 20 mm or less, N represents the number of the magnetic domains, and M represents the number of alternating current phases for driving the motor. Amended claim 16 further requires a stator portion having a plurality of stator coils excitable with alternating current, the permanent magnet surrounding an outer circumference of the stator portion so that the stator coils confront an inner peripheral surface of the permanent magnet, and a bearing portion rotatably and pivotally supporting the

rotational shaft relative to the stator portion so that the rotational body and the stator coils are concentric to each other. No corresponding structural combination is disclosed or suggested by the combined teachings of Shimizu and Hendershot.

Shimizu discloses a permanent magnet and motors (Figs. 6 and 8) equipped with the permanent magnet, as set forth above for amended claim 9. As recognized by the Examiner, the permanent magnet in Shimizu does <u>not</u> have a thickness in the radial direction thereof satisfying the relation $t \leq \pi D/(NM - \pi)$, as recited in independent claim 16.

Moreover, the motors disclosed in Shimizu do <u>not</u> have the specific structure of the motor recited in amended independent claim 16. More specifically, the motor recited in amended claim 16 requires a rotor having a rotational shaft. In contrast, in the inner hub spindle motor 30 shown in Fig. 6 of Shimizu the stator 33, <u>not</u> the rotor 36, has the rotational shaft 32.

Furthermore, amended claim 16 recites that the permanent magnet surrounds an outer circumference of the stator portion so that the stator coils confront an inner peripheral surface of the permanent magnet. No corresponding structure and positional relationship is disclosed or suggested by the inner hub spindle motor 30 and the stepping motor 40 shown in Figs. 6 and 8, respectively, of Shimizu.

For example, in Fig. 8 of Shimizu, the magnets 45, 45' of the stepping motor 40 surround an <u>inner</u> circumference, <u>not</u> an <u>outer</u> circumference, of the stator portion 41.

The secondary reference to Hendershot discloses brushless permanent magnet motors which do not have the foregoing specific structure recited in amended independent claim 16. Accordingly, Hendershot does not cure the deficiencies of Shimizu, and one ordinarily skilled in the art would not have been led to modify the references to attain the claimed subject matter.

Claims 17-19 depend on and contain all of the limitations of amended independent claim 16 and, therefore, distinguish from the combined teachings of Shimizu and Hendershot at least in the same manner as claim 16.

In view of the foregoing, applicants respectfully request that the rejection of claims 9 and 16-19 under 35 U.S.C. §103(a) as being unpatentable over Shimizu in view of Hendershot be withdrawn.

Claim 20 was rejected under 35 U.S.C. §103(a) as being unpatentable over Shimizu in view of Hendershot and further in view of Horikawa. Applicants respectfully traverse this rejection.

Shimizu in view of Hendershot does not disclose or suggest the subject matter recited in amended independent claim 16 as set forth above for the rejection of claims 9 and

16-19 under 35 U.S.C. §103(a). Claim 20 depends on and contains all of the limitations of amended independent claim 16 and, therefore, distinguishes from the combined teachings of Shimizu and Hendershot at least in the same manner as claim 16.

The secondary reference to Horikawa does not cure the deficiencies of Shimizu as modified by Hendershot. For example, Horikawa does not teach the specific structural combination of the motor recited in amended independent claim 16, including the specific structure of the permanent magnet and the specific positional relationship between the permanent magnet and the stator portion. Accordingly, one ordinarily skilled in the art would not have been led to modify the references to attain the claimed subject matter.

In view of the foregoing, applicants respectfully request that the rejection of claim 20 under 35 U.S.C. §103(a) as being unpatentable over Shimizu in view of Hendershot and further in view of Horikawa be withdrawn.

Applicants respectfully submit that new claims 25-34 also patentably distinguish from the prior art of record.

New independent claim 28 is directed to a motor and requires a stator portion having a base and a plurality of stator coils mounted on an outer surface portion of the base, a rotor portion having a rotational body surrounding the outer surface portion of the base, and a permanent magnet mounted on

an inner surface portion of the rotational body so as to confront the stator coils, the permanent magnet having a plurality of magnetic domains magnetized in a radial direction and arranged at regular intervals in a circumferential direction, a thickness t in the radial direction of the permanent magnet satisfying the relation of $t \leq \pi D/(NM - \pi)$, where D represents an inner diameter of the permanent magnet having a value of 20 mm or less, N represents the number of the magnetic domains, and M represents the number of alternating current phases for driving the motor. No corresponding structural combination is disclosed or suggested by the prior art of record.

Claims 25-26, 27 and 29-34 depend on and contain all of the limitations of independent claims 9, 16 and 28, respectively, and, therefore, distinguish from the prior art of record at least in the same manner as claims 9, 16 and 28.

In view of the foregoing, the application is now believed to be in allowable form. Accordingly, favorable reconsideration and passage of the application to issue are respectfully requested.

Respectfully submitted,

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Name

Patricia Petrocelli
Signature

November 30, 2007
Date

6. Die Rückwirkung der Ständerströme

6.1 Feldverzerrung, Entmagnetisierung, Sättigung

Bei optimaler Drehmomentbildung (d.h. Führung des Ständerstromraumzeigers in der Querachse) bildet sich eine Anker-Querdurchflutung aus, die die ursprüngliche Induktionsverteilung der Dauermagnete verzerrt. Bei der Gleichstrommaschine und der dauermagneterregten Synchronmaschine stellt sich dann unter jedem Pol die bekannte Feldverzerrung ein. Die idealisierten Verhältnisse sind in Bild 6.1 dargestellt.

Bei der MDM weist die Feldverzerrung wegen des räumlichen Versatzes der Ständermodule zu den Läuferpolen keinen symmetrischen Verlauf auf. Bild 6.2 zeigt, bei Beschränkung auf die Grundschwingungen der Ständerströme, die idealisierte Feldverzerrung durch Ankerrückwirkung.

Vergleicht man für gleiche elektrische und konstruktive Daten die auftretenden Maximalwerte der MDM

$$\Delta B_{MDM} = \mu_0 \frac{\pi\ R\ \sqrt{2}}{m_{MDM}\ p_{MDM}\ \delta_E} A \qquad (6.1)$$

mit denen einer dauermagneterregten Synchronmaschine

$$\Delta B_{SM} = \mu_0 \frac{\pi\ R\ \sqrt{2}}{m_{SM}\ p_{SM}\ \delta_E} A \quad , \qquad (6.2)$$

so gilt die Beziehung

$$\frac{\Delta B_{MDM}}{\Delta B_{SM}} = \frac{m_{SM}}{m_{MDM}} \frac{m_{MDM} \pm 1}{2} \frac{p_{SM}}{p_{MDM}} \qquad (6.3)$$

($\pm$ für $2p \gtrless 2$), zwischen m und m' gilt Gl.(2.9).

Sie ist in Bild 6.3 über p_{SM}/p_{MDM} mit m' als Parameter dargestellt. Es ergeben sich lineare Zusammenhänge.

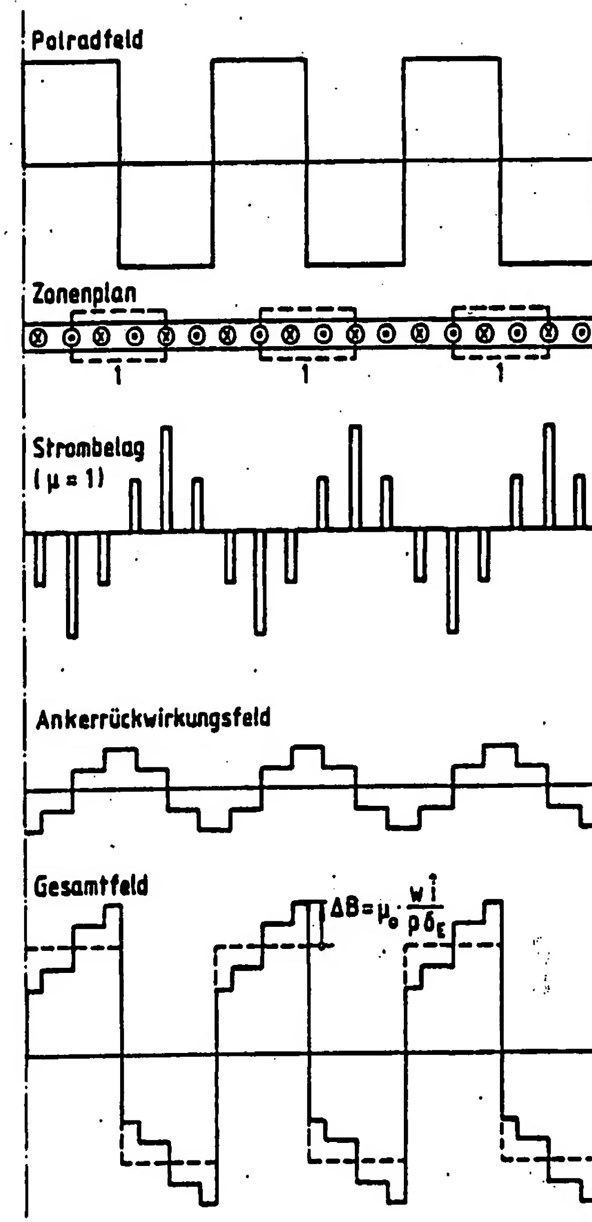

Bild 6.1 : Dauermagneterregte Synchronmaschine m' = 3, N = 18, p = p' = 3, q = 1 (radialer Feldverlauf, Nutöffnung nicht berücksichtigt)

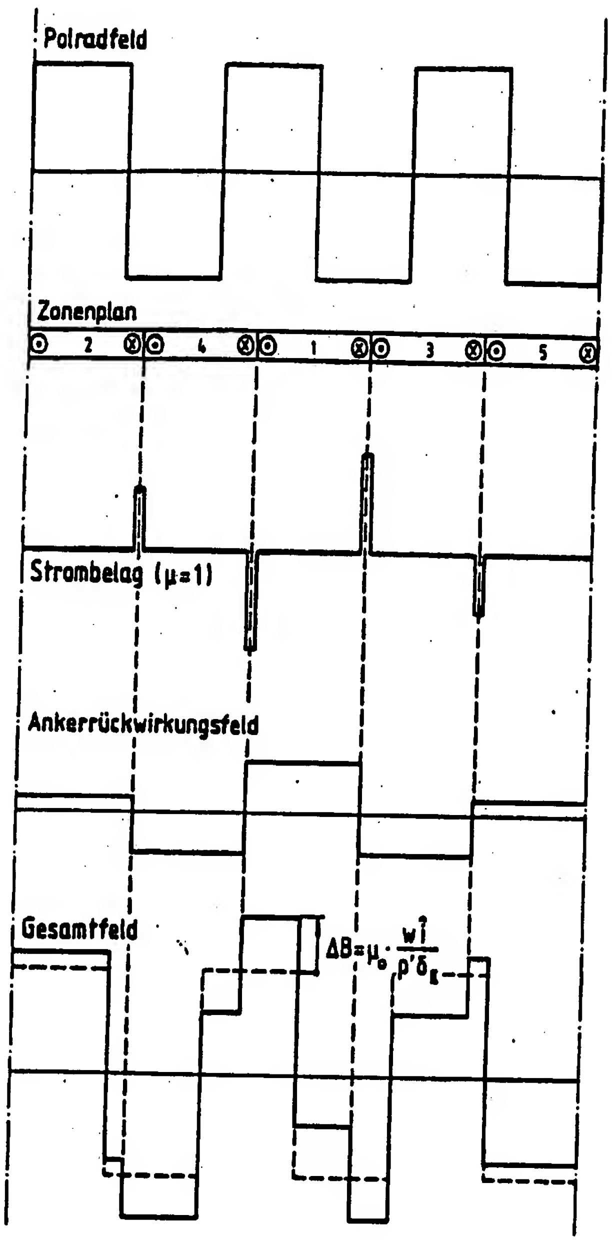

Bild 6.2 : MDM, m'= 5, p'= 1, p = 3
(radialer Feldverlauf, Nutöffnungen nicht berücksichtigt)

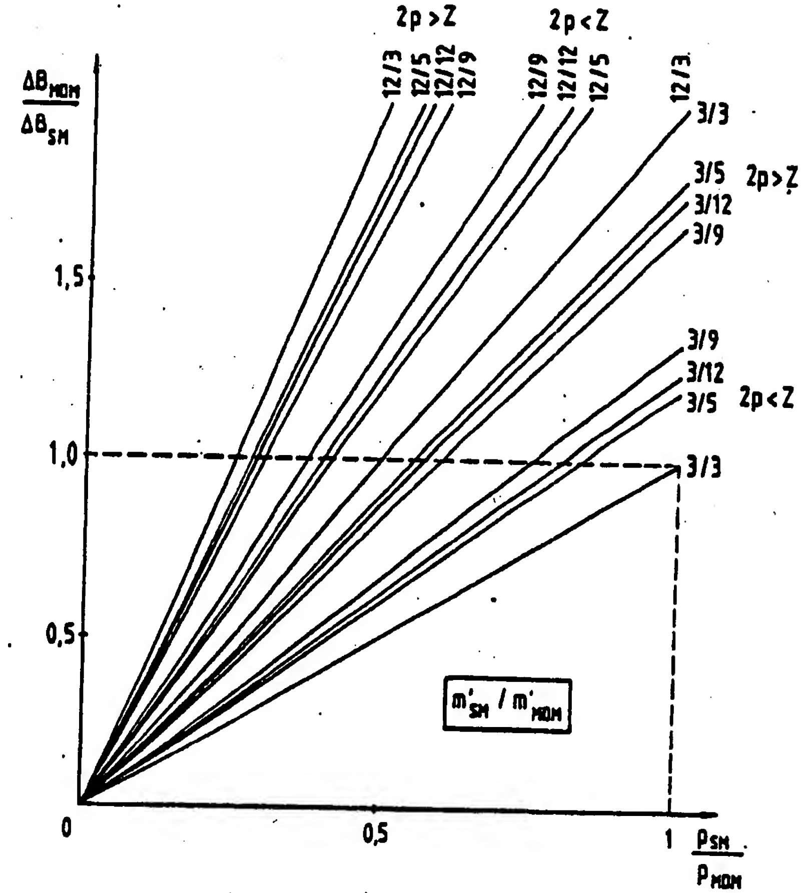

Bild 6.3 : Verhältnis der Maximalwerte

Bei vergleichbaren Polpaarzahlen ist die Feldverzerrung durch Ankerrückwirkung bei der MDM größer als bei der SM.

Mit Rücksicht darauf empfiehlt es sich, die MDM mit relativ hoher Polpaarzahl auszuführen, was bei sonst gleichen Bedingungen zu einer höheren Frequenz führt. Die höhere Polpaarzahl ergibt sich automatisch, wenn man die MDM und die SM unter der Voraussetzung ähnlicher Nutenzahlen miteinander vergleicht. In der Regel ergibt sich dann sogar eine relativ geringe Feldverzerrung bei der MDM.

Beispielsweise entspräche der MDM in Kap. 3, Tabelle 3.1, mit $Z = 28$, $m' = 7$, $2p = 32$ in etwa eine SM gleicher Bohrungsabmessungen mit $N = 30$, $m' = 3$, $2p = 10$ bei $q = 1$. Hierbei müssen jedoch die Joche verstärkt werden.
In diesen Fall wäre $P_{SM}/P_{MDM} = 0{,}313$ und damit $\Delta B_{MDM}/\Delta B_{SM} = 0{,}536$. Dies bedeutet eine erhebliche Verminderung der Feldverzerrung.

Die Feldverzerrung führt in der Regel zu einer entsprechenden Überdimensionierung der Wechselrichter (Stellerreserve), damit die gewünschte Stromeinprägung auch bei Nenndrehzahl sichergestellt werden kann.

Zusätzlich führt sie zu einer Entmagnetisierung der Dauermagnete, die jedoch bei Verwendung von SE-Material im gesamten Arbeitsbereich reversibel ist.

Der Einfluß der Sättigung wird bei theoretischen Untersuchungen in der Regel durch eine entsprechende Vergrößerung der wirksamen Luftspaltlänge berücksichtigt. Da sich die Dauermagnete für das Ankerquerfeld praktisch wie Luft verhalten, ist die Änderung des wirksamen Luftspaltes wesentlich geringer als bei elektrisch erregten Maschinen. Deshalb führen nur starke Sättigungen zu einer spürbaren Beeinflussung des Betriebsverhaltens der (dauermagneterregten) Maschine und sind demgemäß im Gegensatz zur Gleichstromerregung auch zulässig /26/. Begrenzend wirken in erster Linie die Eisenverluste im Ständer.

Die Ankerrückwirkung läßt sich anhand einer numerischen Feldberechnung für die MDM veranschaulichen. Bild 6.4 zeigt für die in Kap. 3 angegebene MDM das resultierende magnetische Feld sowie die Radialkomponente der Luftspaltinduktion. Der Berechnung liegt ein zeitlicher Verlauf der Strangströme gemäß Bild 4.1 ($I = 50$ A) zu Grunde. Die Grundschwingungen der Strangströme haben die gleiche Phasenlage wie die entsprechenden Polradspannungen.
Die idealisierte Verteilung des Strombelags und das (Anker-) Rückwirkungsfeld allein sind zusätzlich dargestellt.

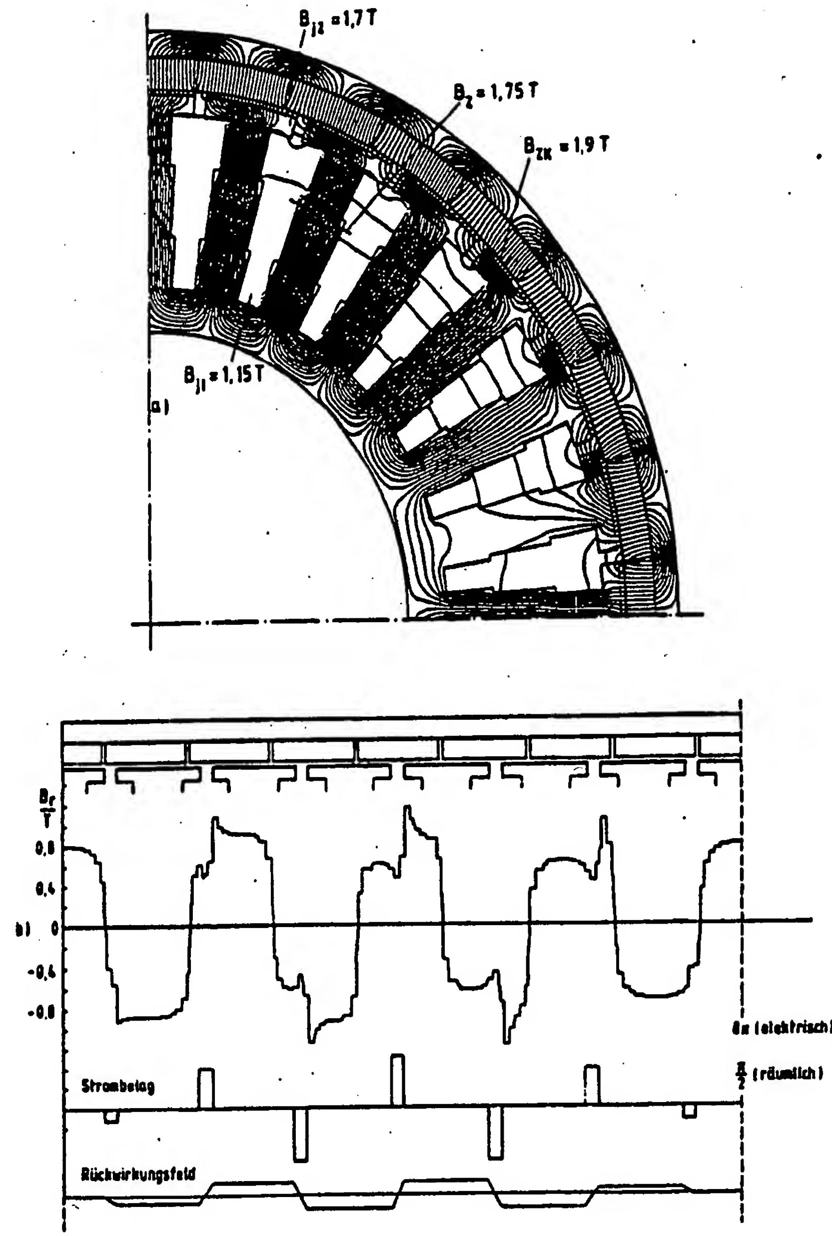

Bild 6.4 : Feldbild (a) und resultierende Radialkomponente der Luftspaltinduktion (b)

Ein Vergleich von Bild 6.4 mit Bild 3.4 bestätigt die Feldverzerrung durch das Ankerrückwirkungsfeld.

Es ist weiter ersichtlich, daß einzelne Ständermodule aufgrund des "Nebenschlusses", den die Zahnköpfe zum magnetisch wirksamen Luftspalt bilden, relativ stark belastet werden.

6.2 Wirbelstromverluste im Läufer

Grundsätzlich erzeugt jede Komponente des Ständerstrombelags im Magnetmaterial und im Läuferjoch Wirbelstromverluste.

Von besonderer Bedeutung sind diejenigen von der Grundschwingung des Stromes erzeugten Drehwellen, deren Wicklungsfaktor mit dem der Hauptwelle übereinstimmt. Das trifft insbesondere für die zweite (gegenlaufende) Hauptwelle zu. Die Gesamtverluste erhält man durch Addition der Teilwellenverluste.

6.2.1 Berechnungsmodell

Zur näherungsweisen Berechnung werden die Magnete und das Läuferjoch durch homogene Schichten der Permeabilität μ_1 bzw. μ_2 und der elektrischen Leitfähigkeit κ_1 bzw. κ_2 ersetzt.

Die Polteilungen der maßgeblichen Wellen sind im allgemeinen kleiner als die Länge der Maschine. Deshalb entsteht im wesentlichen eine axiale Strömung, auf die sich die Betrachtung beschränken soll.

Weiterhin kann die Krümmung des Läufers im Vergleich zu den maßgeblichen Polteilungen vernachlässigt werden, so daß kartesische Koordinaten verwendet werden können. Der Umfang der Maschine wird dazu in der Ebene abgewickelt.

Die Wirbelstromkomponenten berechnen sich aus den magnetischen Feldstärken, die für die Schichten (vergl. Bild 6.5) Luftraum (Index 0), Magnetmaterial (Index 1) und Joch (Index 2) aus der Potentialgleichung zu bestimmen sind.

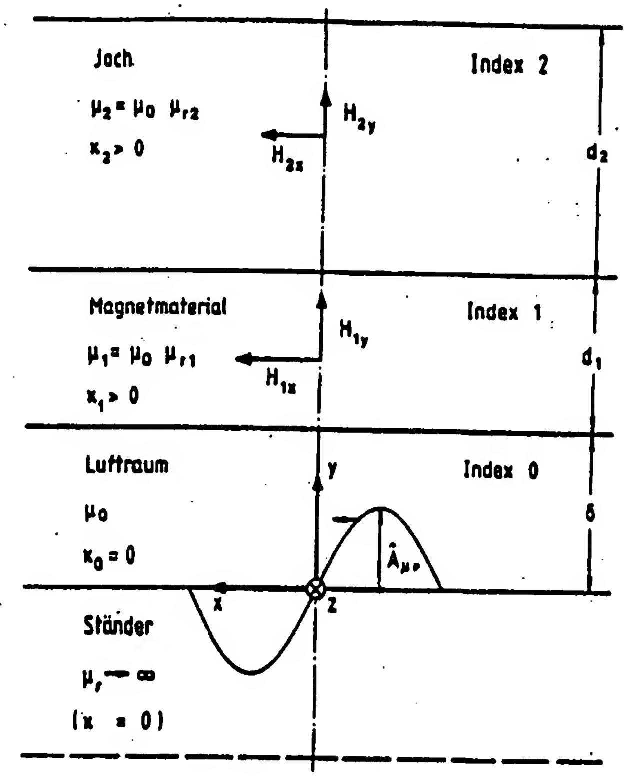

Bild 6.5 : Kartesisches Koordinatensystem zur Berechnung der Wirbelstromverluste

Die Verlustleistung durch Wirbelströme läßt sich entsprechend /1/ über den POYNTING'schen Vektor bestimmen.

Zur Lösung der Potentialgleichung für die Tangential-Komponente

$$\frac{\partial^2 \underline{H}_x}{\partial x^2} + \frac{\partial^2 \underline{H}_x}{\partial y^2} = \mu\,\kappa \cdot \frac{\partial \underline{H}_x}{\partial t} \qquad (6.4)$$

empfiehlt sich ein Ansatz in der Form des erregenden Strombelages